TABLE 1.—*Duststorms at Amarillo, Tex.*—Continued

Date	Visibility	Prevailing wind direction during duststorm	Duration of duststorm	Duration of lowest visibility	Highest wind velocity during duststorm
Year, 1934—Continued	*Miles*		*Hours*	*Hours*	*M.p.h.*
Apr. 12	2	NE	4	2	14
Apr. 13	3	SW	4	2	28
Apr. 14	4	NW	2	1	30
Apr. 22	2	E	6	2	26
Apr. 23	3	SW	11	7	18
Apr. 24	2	E	19	7	24
Apr. 25	5	S	5	3	30
Apr. 26	1	N	6	3	28
Apr. 27	2	NE	5	2	34
May 3	4	SW	2	1	35
May 4	2	NW	4	2	18
May 13	1	N	5	1	40
May 14	5	N	3	1	28
June 15	5	S	1	1	18
June 20	5	NW	5	3	17
June 22	6	SW	4	4	32
July 5	2	SW	8	1	20
Aug. 2	6	S	5	5	16
Sept. 2	1/2	NE	8	1	60
Sept. 5	5	NE	4	1	40
Sept. 6	6	NE	2	1	49
Sept. 20	3	NE	7	1	48
Sept. 22	1/4	S	1	1	42
Sept. 25	6	SW	2	2	40
Oct. 8	5	NE	1	1	17
Oct. 15	2	S	8	3	44
Nov. 2	1/2	SW	11	1	44
Nov. 4	1	NW	8	2	46
Nov. 27	1/2	NW	14	2	36
Dec. 1	4	W	4	2	38
Dec. 2	3	NW	7	2	28
Dec. 6	1 1/2	NE	1	1	26
Dec. 31	3/4	N	4	4	52
Year, 1935					
Jan. 3	5	NE	7	5	27
Jan. 12	2	W	4	2	41
Jan. 12-13	2	NE	8	2	39
Jan. 16	1/4	W	10	1	56
Jan. 17	5	SE	4	1	29
Jan. 19	6	SE	1	1	28
Jan. 20	4	N	2	1	26
Jan. 21	6	NE	1	1	19
Feb. 13	3	SW	6	2	40
Feb. 14	4	NW	1	1	24
Feb. 15	1/2	N	11	1	30
Feb. 16	6	N	2	2	34
Feb. 17	6	NE	1	1	8
Feb. 18	1 1/2	W	7	3	15
Feb. 21	3/4	W	12	2	42
Feb. 21-22	0	NE	11	1	46
Feb. 22	4	SW	3	1	7
Feb. 23-24-25	0	N	56	1	44
Feb. 27	6	SW	1	1	18
Feb. 28	1 1/2	SW	9	2	34
Mar. 3	0	W	4	11	48

TABLE 1.—*Duststorms at Amarillo, Tex.*—Continued

Date	Visibility	Prevailing wind direction during duststorm	Duration of duststorm	Duration of lowest visibility	Highest wind velocity during duststorm
Year, 1935—Continued	*Miles*		*Hours*	*Hours*	*M.p.h.*
Mar. 4-5	0	W	18	1	52
Mar. 5	1/8	W	8	1	37
Mar. 6	1/2	N	4	1	44
Mar. 8	4	S	8	2	35
Mar. 13	5	NE	1	1	20
Mar. 15-16-17	0	S-SW-N	55	3	50
Mar. 18	3/4	SW	1	1	38
Mar. 19	1/4	N-SW	14	4	28
Mar. 20	1/4	SW	8	1	44
Mar. 21	2	SW	5	1	30
Mar. 22	3	SW	1	1	28
Mar. 26	3	W	2	1	25
Mar. 27	0	NE	19	8	46
Mar. 28-29-30-31	0	SW to NE	83	6	36
Year, 1936					
Feb. 3	1/4	N	10	1	38
Feb. 7-8	0	SW-NW	23	5	40
Feb. 9	1	SW-NW-NE	15	2	40
Feb. 12-13	1	W-N-N-E	21	2	35
Feb. 13-14	1/8	SW-W-NE	22	1	44
Feb. 14	5	SE	5	3	18
Feb. 16	2 1/2	SE	3	2	30
Feb. 17	1	NE	8	2	30
Feb. 23	1/2	SW	12	2	38
Feb. 24	1/2	SW	8	3	44
Feb. 25	1	NW	7	1	10
Feb. 25	1 1/2	W	4	1	32
Feb. 26	1/2	NW	8	1	20
Mar. 1	0	NE	4	1	40
Mar. 3	3	SW	4	1	20
Mar. 4	1/2	NE	10	1	38
Mar. 5	3	S	4	1	30
Mar. 10	0	NE	13	1	40
Mar. 12	4	SW	16	1	33
Mar. 13-14	0	E-SE-S	12	2	29
Mar. 14-15	1/4	NE	7	1	30
Mar. 15-16	0	N	7	4	48
Mar. 16	1 1/2	N	7	1	24
Mar. 17	3	SW	6	1	16
Mar. 17	1	SW	12	2	40
Mar. 19	0	NE	8	1	36
Mar. 21-22	0	S-SW	17	2	42
Mar. 22	0	SW	13	3	52
Mar. 23-24	0	SW-W	19	9	56
Mar. 24	1	SW	4	1	36
Mar. 25	0	SW-W	15	1	42
Mar. 26	3/4	E-SE	14	1	28
Mar. 27	1 1/4	SE-SW	10	2	13
Mar. 28	1 1/2	W	3	1	33
Mar. 29	1	W	6	2	27
Mar. 30	2	W	5	1	28
Mar. 30	0	NE	11	1	40
Mar. 31	1 1/2	SE	8	1	38

WINTER AIR-MASS CONVERGENCE OVER THE NORTH PACIFIC [1]

By ROBERT W. RICHARDSON

[University of California, Berkeley, May 1936]

This paper is the result of a study of storm tracks in their relations to frontal zones and to the distribution of air masses over the North Pacific Ocean. Upon the completion of cyclone frequency maps, the question of the location of the Pacific polar front appeared to be significant; a comparison of the maps with Bjerknes' map of the principal fronts in the Northern Hemisphere [2] reveals discrepancies that can hardly be accounted for by mechanical errors or incomplete data. It is admitted that the frontal zone shifts its latitude with the seasons; the question dealt with here concerns only the mean position of the polar front during the winter.

Figure 1 is based on the map and figure [3] employed by the authors of Physikalische Hydrodynamik, and illustrates the application of their theory in establishing the position of the Pacific polar front in winter from the mean pressure map for February. The underlying principle is that a front is produced by a particular combination of air movements that may graphically be represented by stream lines and is termed a deformation field. A typical frontogenetic deformation field is illustrated in the inset in figure 1. Considering the stream lines to conform to gradient winds in the Northern Hemisphere, the distribution of pressure will be as indicated. If the deformation field is to produce a front, however, it must be superimposed on an appropriate temperature field. The isotherms of such a field are indicated by the broken lines—temperature decreasing toward the top of the diagram. The warm air entering the deformation field from below, and the cold air brought in from above, escape along the axis of extension to the left and to the right. It is only along the front to the right of the intersection of axes, where the direction of the gradient wind produced by the frontal solenoidal field is opposite to that of the wind in the warmer current, that the equilibrium of the atmosphere is disturbed, and wandering cyclones are generated.

If these principles are applied to the map of mean pressure for February, upon which the sea level temperature field for February [4] has been superimposed, it is to

---

[1] Presented before the Association of Pacific Coast Geographers, Los Angeles, Calif., June 27, 1935.

[2] Bjerknes, V., et al., Physikalische Hydrodynamik, Berlin, 1933, 708, fig. 130.

[3] Op. cit., 703, fig. 127; 708, fig. 130.

[4] Isotherms from Schott, G., Geographie des Indischen und Stillen Ozeans, Hamburg, 1935, plate VI.
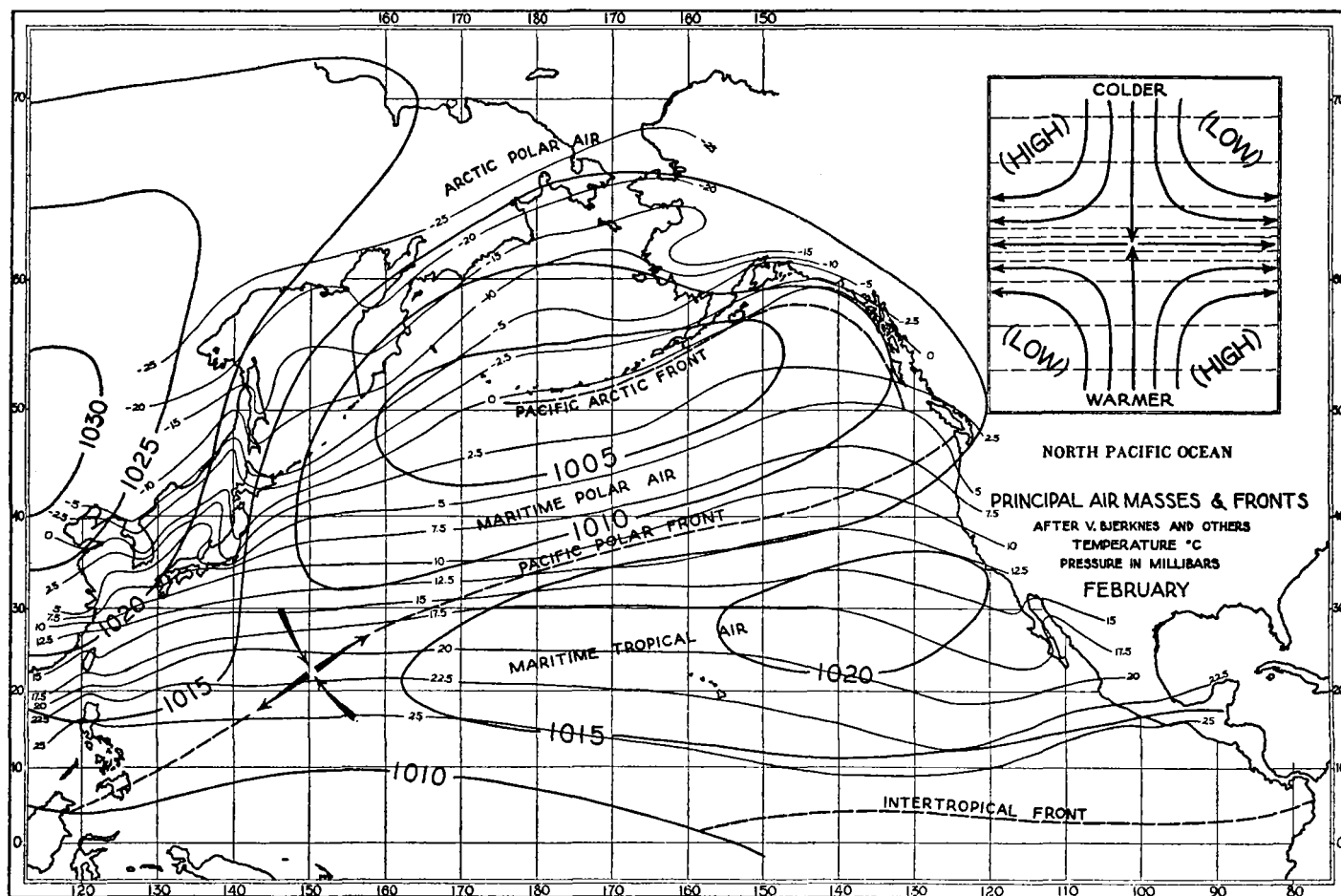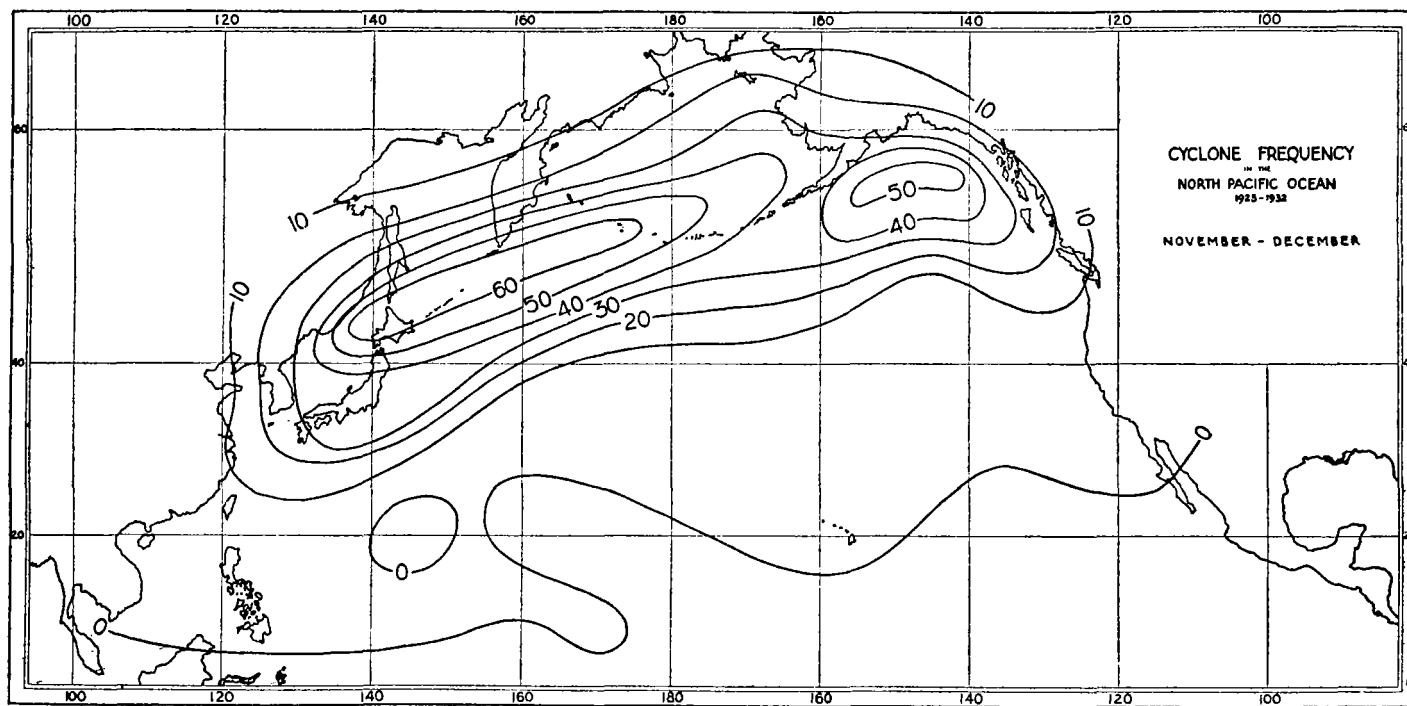
FIGURE 1.

FIGURE 2.

be observed that both the distribution of pressure and the course of the mean isotherms support Bjerknes' thesis.

The air masses separated by the Pacific polar front are indicated as maritime polar air to the north, and maritime tropical air to the south. Polar continental air is thought of as coming along the isobars between the Asiatic HIGH and the Aleutian LOW, and being rendered unstable by its movement over the ocean surface.

The less questionable Pacific arctic front, which extends from the Aleutian Islands across the Gulf of Alaska, separates arctic polar air (polar continental air) from originally polar continental air that has circulated over the ocean and become maritime polar air. The explanation offered is that the coastal mountains cause the latter mass of air, which is moving from the southwest, to ascend, thereby forming a front between the maritime

during the decade of observation, while the front itself passes through a zone having fewer than 10 cyclones. Attention may also be called to the apparently independent zone of frontogenesis existing in the Gulf of Alaska. This is exceptionally well marked on the November-December map (fig. 2), and also on the map for March-April (fig. 4). The absence of a clear development of this zone on the January-February map may be attributed either to incomplete observations or to a thus far unaccounted-for diminution in frontal development at this time of the year. The March-April map is considered to be the last of the series that is representative of winter conditions. This conclusion is based on the examination of similar maps made for the 6 summer months (May to October, inclusive, not reproduced here). With the exception of the September-October map, which shows a
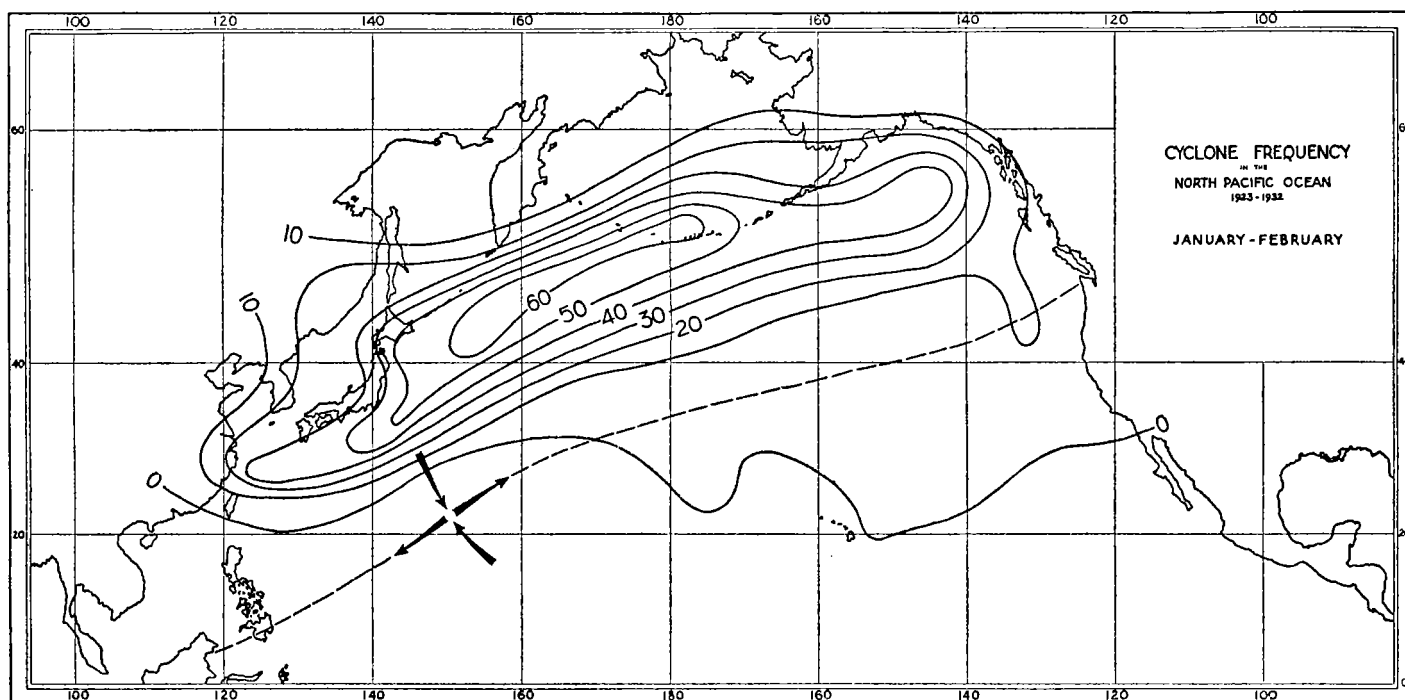

FIGURE 3.

polar air aloft, and the denser arctic polar air at ground levels.

The location of the Pacific polar front along the axis of extension of a deformation field indicated by maps of mean pressure does not agree with the indications of daily weather maps of the North Pacific. This contention is essentially based on the maps of frequency of cyclones (figs. 2, 3, and 4), on the ground that the axis of the region of greatest frequency indicates the mean position of the front. The isarithms on these maps represent total cyclonic frequency during the 10-year period ending with 1932. These frequencies were tabulated for bimonthly intervals, starting with January-February, and were plotted for each 5° square of latitude and longitude. The original data were obtained from the maps of cyclone tracks appearing in the Japanese "Daily Weather Charts of the North Pacific Ocean".[5]

For comparative purposes, the Bjerknes, polar front has been shown on the January-February map (fig. 3) in order to point out that the neutral point of the deformation field falls in an area registering no cyclone tracks

fairly well developed zone of maximum frequency extending from Sakhalin to the Aleutian Islands, neither of the other maps displays any intelligible pattern.

Figure 5, depicting winter air masses and fronts in the North Pacific, is a graphic representation of the conclusions derived from examination of the maps of frequency of cyclones. In answer to the query regarding the location of the Pacific polar front, the dashed line extending from the East China Sea to the Bering Sea is the mean axis of maximum cyclone frequency, and represents, presumably, the mean winter position of the Pacific polar front. On the basis of frequency alone it is apparent that polar air moving off the Asiatic continent converges with air of tropical origin more frequently in the general region of the East China Sea than in any other place in the western North Pacific. In fact, in agreement with Mitchell's [6] earlier findings, Byers [7] states that 70 percent of the frontal systems of the North Pacific area have their origin in this region. Sekiguti [8] furnishes corrobo-

---

[5] Imperial Marine Observatory, Kobe, Japan ,Daily Weather Charts of the North Pacific Ocean. Appendices, 1923–32, inclusive.

[6] Mitchell, C. L., Cyclones and anticyclones of the northern hemisphere, Monthly Weather Review, vol. 58, pp. 1–22, 1930, particularly pp. 10, 13, and fig. 15, p. 14.
[7] Byers, H. R., The Air Masses of the North Pacific, Bull. Scripps Inst. Oceanography., Tech. Ser. v. 3, no. 14, 311–354, 1934.
[8] Sekiguti, K., et al., On the Characterization of Winter, Mem. Imp. Marine Obs, v. 2, no. 1, 1–7, 1925.

rative temperature data for that portion of the front which passes through or in the vicinity of the Japanese islands, in addition to identifying the air masses separated by the front. In this pioneer study it is pointed out that in the area comprising the Japanese archipelago there are "two regions [that] can be reasonably regarded separate ones having different laws of temperature distribution." The line (polar front?) separating these two regions is identified by the comparatively steep temperature gradient to the north of the line in contrast to the

more isothermal distribution to the south. The northern region, referred to as "subpolar", and the southern "subtemperate" region correspond, respectively, to the air masses designated in figure 5 as P_C and T_P, the latter of which may be thought of as N_{TP} in the vicinity of the
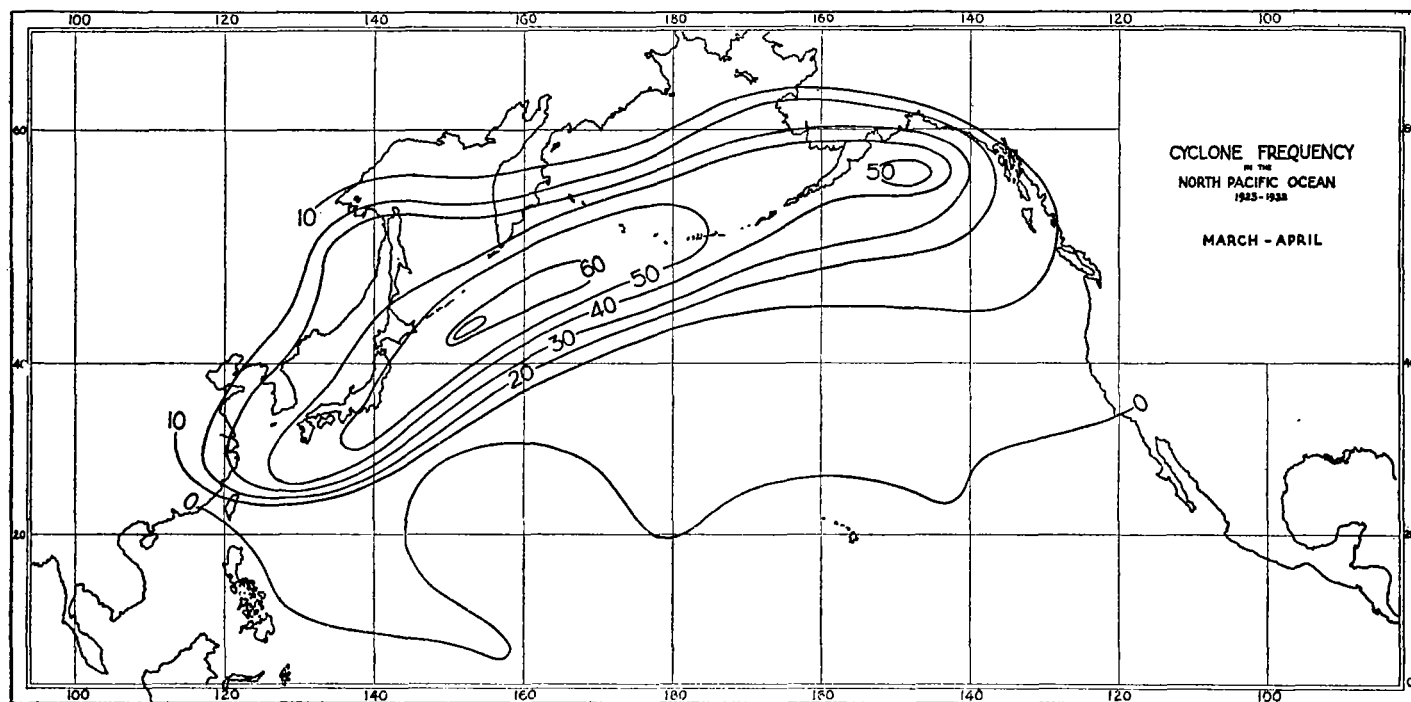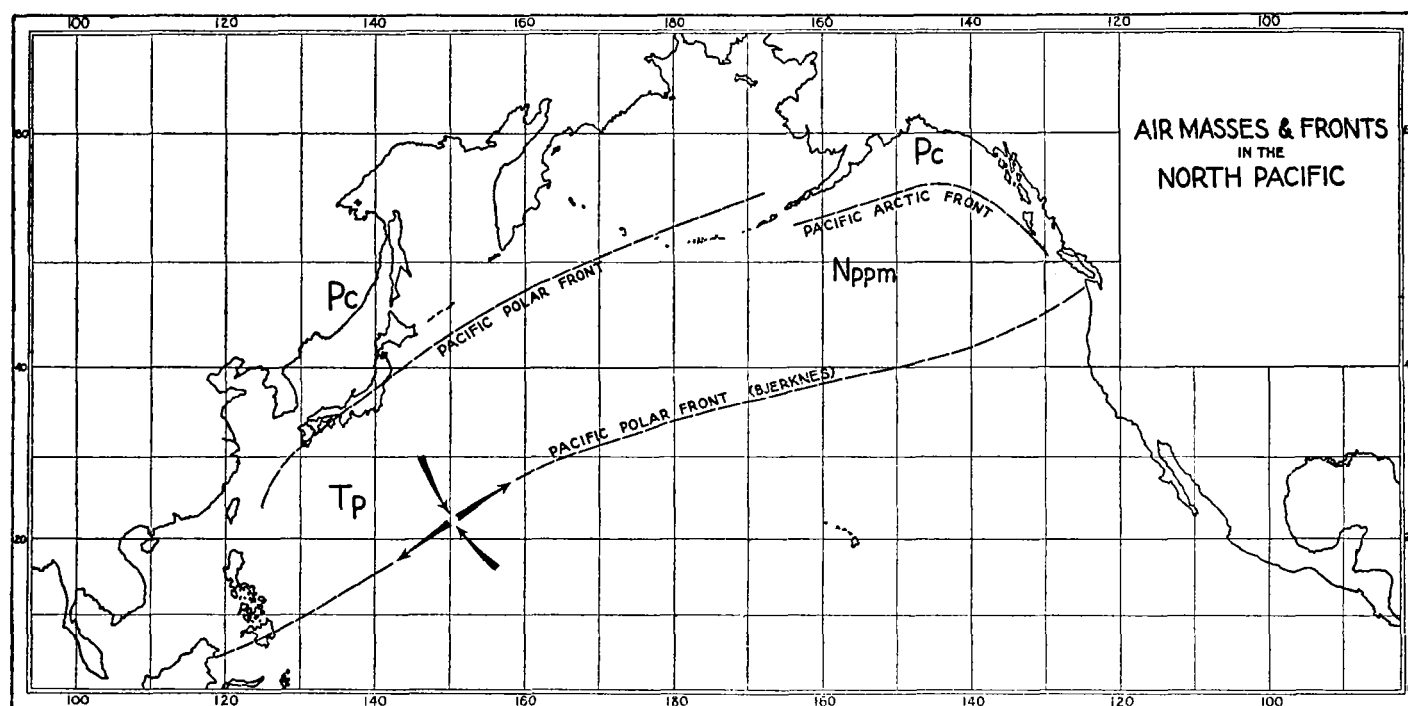

FIGURE 4.

FIGURE 5.

Japanese islands. The polar continental air leaking out from the Asiatic monsoon HIGH is cold, consequently dense and dry; and before coming into contact with another air mass, does not cross a sufficient ocean surface to lose these characteristics or become modified. The

tropical air mass, on the other hand, is of marine origin, and is thus relatively warm, light, and near the saturation point.

Since no consistent temperature data exist for the area over the ocean, neither the location of the front nor the identity of the air masses can be predicted with the same degree of certainty. If, on the other hand, the mean position of the polar front is correct in its western reaches, there is no logical reason to assume that the front would be displaced equatorward in its eastern extension.

What has been attempted, and illustrated in figure 5, is essentially a revision of the Norwegian map on the ground that the establishment of a front from a deformation field, regardless of how clearly that field exists on the mean pressure map for February, is contrary to the facts revealed by actual observational data.

As previously mentioned, the discrepancies in the location of the Pacific Arctic front are slight. It is generally agreed that there exists in this region a distinct zone of frontogenesis and cyclonic degeneration. The explanation of this seeming paradox is that cyclones which are dying out after occlusion are often regenerated when fresh air masses are brought into them. The mean position of this front has been derived in the same manner as that of the Pacific polar front. The results thus obtained were checked with Werenskiold's[9] maps of mean monthly air transport, and strong agreement was found to exist between his lines of air convergence and the mean path of storms. The designations of the air masses (fig. 5) were derived principally from the synoptic weather maps of the California Institute of Technology and from Byers'[10] paper. According to these sources of information it is inferred that polar continental air, flowing out through the larger river valleys of Alaska, converges with N_{PPM} or N_{PC} air which has crossed the North Pacific.

[9] Werenskiold, W., Mean Monthly Air Transport Over the North Pacific Ocean, Geofysiske Publikationer, v. 2, no. 9, 1922.
[10] Op. cit., 322.

INFLUENCE OF LAKE PONCHARTRAIN ON FOG FORMATION AT SHUSHAN AIRPORT, NEW ORLEANS, LA.

By GEORGE V. FISH

[Weather Bureau, New Orleans, March 1936]

The importance of fog as a hazard to the operation of aircraft has been an incentive to study and analyze the various conditions which favor its formation. These studies, particularly those by Willett (Synoptic Studies in Fog, M. I. T. Meteorological Papers, 1930), have added much to current knowledge, and are the basis upon which the increasingly accurate forecasts of fog conditions are made by the United States Weather Bureau airway district forecast centers; to add further a knowledge of factors which have a direct bearing on particular local situations should prove of value to forecasters, particularly where an important air terminal is involved.

Shushan Airport, at New Orleans, La., is constructed on dredged land, inclosed by a concrete sea wall, on what formerly was a portion of the bottom of Lake Ponchartrain. The airport extends out into the lake in the shape of a blunt arrowhead, with facilities for both land and sea planes. The fill was completed to an average height of approximately 6 feet above water level. Lake Ponchartrain is classified as salt water; there is often a definite tidal influx which, however, is probably more than counterbalanced by the outflow from numerous fresh-water bayous which empty into Ponchartrain, so that the introduction of warm water from the Gulf of Mexico is confined to a very small section.

At its widest point, in a north-south direction, Lake Ponchartrain is about 25 miles across; roughly pear-shaped, it is approximately 40 miles along the east-west axis. Shushan Airport is on the south shore of the lake, near the point where it is widest. To the eastward, Lake Ponchartrain empties into Lake Borgne, another body of salt water, which is influenced to a greater extent by tides from the Gulf of Mexico.

The surrounding terrain is level delta land for many miles, not varying more than a few feet in elevation except for the levee works along the river and canals. The only impediments to the free flow of air along the level surface from all directions are the comparatively narrow strip of timber to the southeast and the city of New Orleans to the southwest. To the northwest, north, and northeast, nothing bars the free flow of air from off the lake. It is because of this circumstance that rapid changes in visibility and, less often, in ceiling, are sometimes observed.

From a knowledge of the changes that are known to occur in oceanic surface water temperatures, it may be assumed that marked changes in temperature occur seasonally in Lake Ponchartrain, and that these changes may sometimes be greatly intensified during a comparatively brief period.

McDonald (Seasonal Variations in North Atlantic Surface Temperatures, Trans. Am. Geophysical Union, 1935), using some material compiled by Schott, and supplementing it from data in the files of the Marine Division of the United States Weather Bureau, has shown that the annual range of surface water temperatures in the Gulf of Mexico in close proximity to Lake Pontchartrain is slightly more than 20° F. His investigation led him to the conclusion that "Intensified local cooling of a portion of the ocean surface occurs more readily than local warming."

If we may apply this conclusion here, which appears reasonable, and make further allowance for increased cooling due to closer proximity to the sources of extremely cold polar air, and for the fact that little if any warmer water is introduced by tidal action, we may assume that the surface waters of Lake Pontchartrain cool very rapidly with the coming of the winter season; and after a particularly severe cold wave, they may be further cooled, until a large difference in temperature exists between a mass of warm moist air advancing inland from the Gulf of Mexico, and the surface of Lake Pontchartrain.

The change from cold continental air to warm Gulf air usually is rapid. Since the surface waters of the lake respond more quickly to cooling processes than to warming, the difference in temperature between the water surface and the warm air mass will not be appreciably diminished during the average time required for translation of warm-air masses across the lake surface. During the period of translation, surface cooling of the air mass takes place, and surface fog over the lake normally results.

The formation of this surface fog may partially explain why surface cooling takes place more readily than surface